

Upgrading the Linac 400 MeV Switchyard

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This note describes changes in the 400 MeV beam transfer system from the Linac to improve the quality of the beam delivered to the Booster and to add the capability to direct beam to the MuCool Test Area (MTA). The new configuration has two pairs of pulsed dipole magnets on each side of the 400 MeV electrostatic Chopper. The smaller pair deflects vertically to replace the kick of the Chopper to send the beam to the Booster while the larger pair deflects horizontally to transfer the beam to the MTA. In this new scheme, the Chopper is uncharged while the beam is injected into the Booster such that the injection position does not rely on Chopper power supply regulation as it does now. A feature of the proposed upgrade is that no changes in the lattice functions are required in the lines to the Booster or to the Dump; once the four new magnets are installed, the switch between the old and new operating modes can be done from upstairs. The transfer to the MTA is already described in a previous note (MUC-NOTE-COOL_EXP-287), but below we add additional details and comments.

Introduction

Historically, the Chopper selected the part of the Linac pulse to be sent to the Booster. With both of the Chopper's horizontal plates charged to 56 kV, the front portion of the beam pulse passed straight through them to the Linac Dump. Then one plate was discharged causing a vertical deflection of the middle portion of the beam toward the Booster. Once the desired number of Booster turns was injected, the second plate was discharged to allow the rest of beam to go straight to the dump. Thus the amount of beam discarded from the first part of the Linac pulse and the number of Booster turns were simply determined by the timing of the discharging of the Chopper electrodes. Since the discharge of the electrodes is fast, little beam is lost during transitions.

Present and Proposed Operation to the Booster

After the 400MeV upgrade, the time in the Linac cycle that the first electrode discharged was fixed so that a feed forward system could be implemented in the upgraded debuncher cavity. Also, to lower the Chopper voltage required for the higher energy extraction, a defocusing quad (Q2) was introduced. Then, in early 2000, the 750keV Chopper became

the method to control the beam pulse duration and consequently the number of Booster turns, such that there is no longer any tail portion of the 400 MeV Linac pulse to be discarded.

In the proposed scheme, two small dipole magnets on each side of the Chopper replace it to provide the needed vertical deflection for transfer to the Booster. For straight-ahead transfer to the Dump, the Chopper is on and deflects downward to cancel the upward bend of the two small dipoles. Thus the Chopper will start out with only one plate charged as the unwanted initial Linac beam is directed to the Dump and then it will quickly discharge to switch to the Booster beam line.

Figure 1 shows a Trace3D diagram of the present configuration used to transfer beam to the Booster. After Q1, the Chopper deflects the beam upward through Q2, which produces an additional upward kick. In this and subsequent diagrams the vertical position of the beam centroid is corresponds to the bold line.

Figure 2 shows a Trace3D diagram of the proposed configuration to transfer beam to the Booster. The Chopper is grounded. Two small dipole magnets on each side of the Chopper effectively replace it to deflect beam upward through Q2, as before. There is effectively no difference between Figures 1 and 2, where the two vertical dipoles on either side of the Chopper replace the Chopper kick. To the extent that the two dipoles are close to the Chopper, the trajectory through the Chopper is the same in both figures. In any case, the same clearance can be had in the two cases if the Chopper position is raised slightly for Figure 2.

Figure 3 shows a Trace3D diagram of the present configuration used to transfer beam to the Dump. Both Chopper plates are at the same voltage, providing no deflection. The beam ends in the Linac Dump after the Spectrometer magnet.

Figure 4 shows a Trace3D diagram of the proposed configuration to transfer beam to the Dump. In this case, the Chopper bends the beam downward to counter the upward bends from the two small dipoles on each side of the Chopper to send the front portion to the dump. The discharge of the Chopper causes a fast switch from the Dump to the Booster.

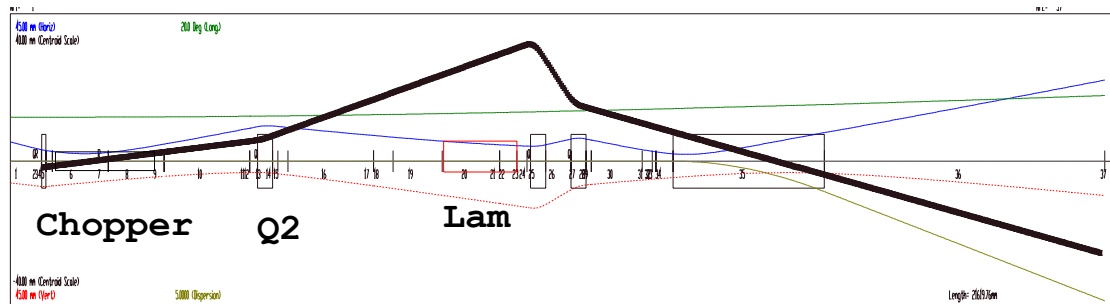


Figure 1. Trace3D elevation diagram of the present 400 MeV transfer system from the Linac to the line down to the Booster. The position of the beam centroid is shown as a bold line. For beam to be injected into the Booster, the Chopper must provide a vertical deflection that is amplified by the defocusing quad, Q2.

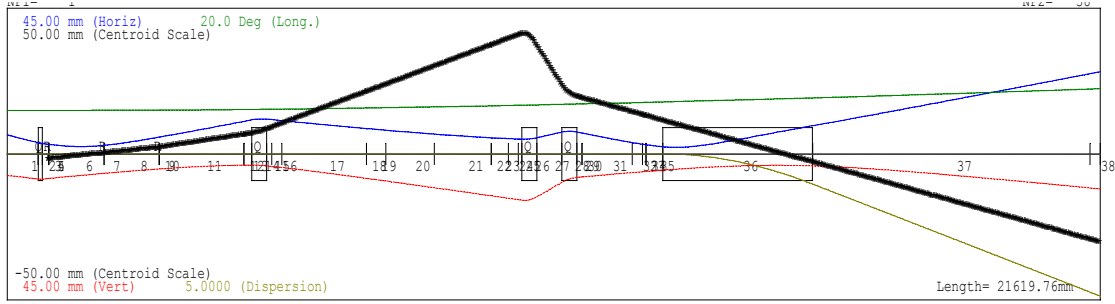


Figure 2. Trace3D elevation diagram of the proposed 400 MeV transfer system from the Linac to the line down to the Booster. For beam to be injected into the Booster, the Chopper is grounded and two small dipole magnets, one on each side of the Chopper, provide the vertical deflection that is amplified by the defocusing quad, Q2.

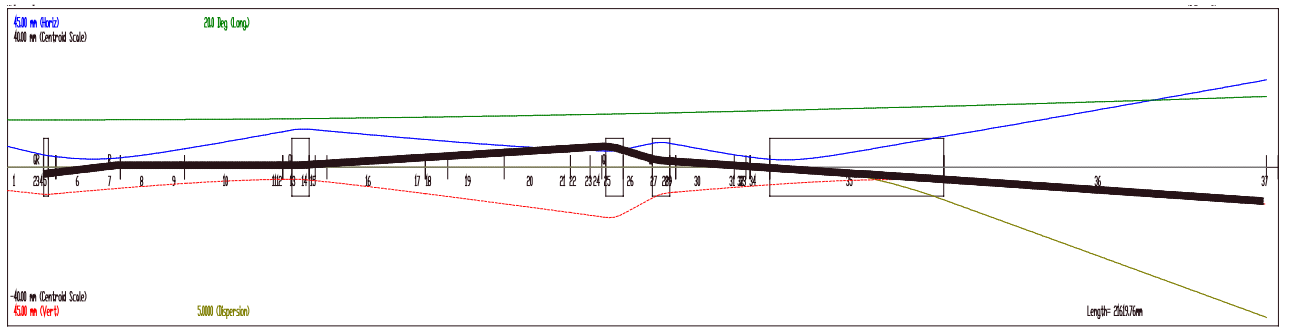


Figure 3. Trace3D elevation diagram of the present 400 MeV transfer system from the Linac to the line to the Dump. The Chopper provides no deflection for the unwanted initial portion of the beam to be dumped.

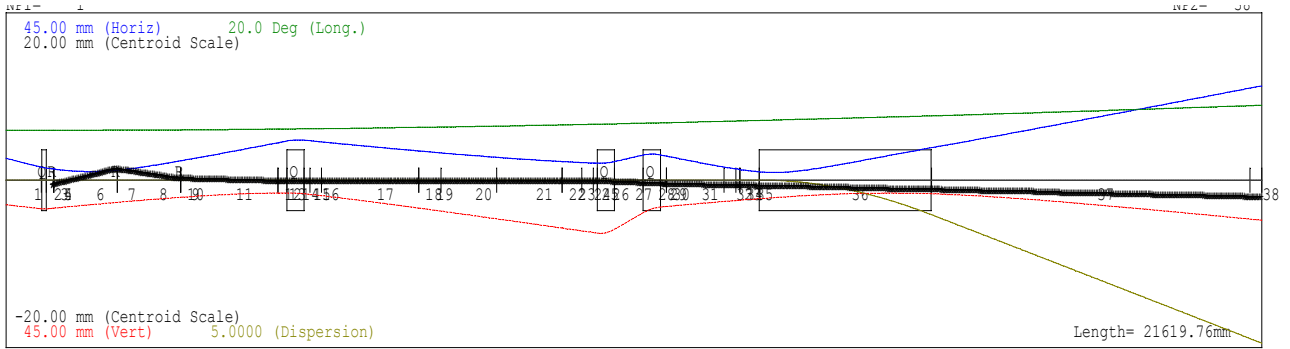


Figure 4. Trace3D elevation diagram of the proposed 400 MeV transfer system from the Linac to the line to the Dump. Here the Chopper deflects the beam downward to compensate the upward bend of the new pulsed-dipoles on each side of the Chopper.

The pulsed vertical dipoles have to create a 5mr bend. Two magnets, each with 3 kG-in line integral on each side of the Chopper, satisfy this requirement.

An initial test of this new scheme to send beam to the Booster can be performed by adding a new dipole corrector between Q74 and the wire-scanner in front of the Chopper

or by moving the exiting corrector from the end of the Linac to this location. The first Chopper plate has to discharge before the beam comes and the second plate at the time that beam has to be sent to the Booster.

Operation to the MTA

The description of the proposed MTA beam line is contained in MuCool Note 287 (MUC-NOTE-COOL_EXP-287). The two horizontal pulsed dipoles on each side of the Chopper create enough deflection such that the MTA beam pipe passes outside of the Q2 magnet and enters the first cooling ring dipole as shown in Figure 5.

An essential feature of this layout is that the beam does not pass through the centers of the first two cooling ring dipoles. These magnets have 12-inch wide apertures with ± 5 -inch good field region for accelerator performance and so the beam pipe can be right up against the coil package to provide the needed clearances as shown in Figure 5.

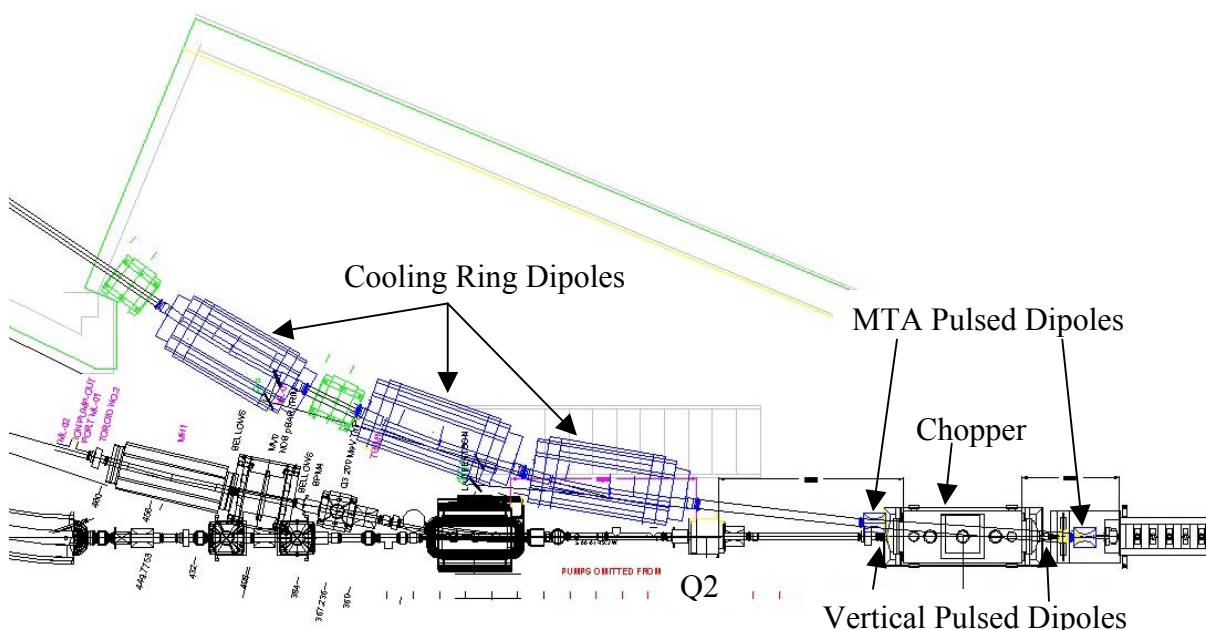


Figure 5. Diagram of the start of the Linac-to-MTA transfer line. The first two cooling ring dipoles are not centered on the beam, but are offset to eliminate interference with the straight-ahead beam line magnets.

An example of Cooling Ring Dipole is shown in Figure 6. Figure 7 shows the upstream face of the Q2 magnet, where a 3-inch beam pipe is shown to easily miss the magnet structure.



Figure 6. Cooling Ring Dipole magnet in storage, showing 12-inch gap width. The magnet characteristics are described in TM-0777.

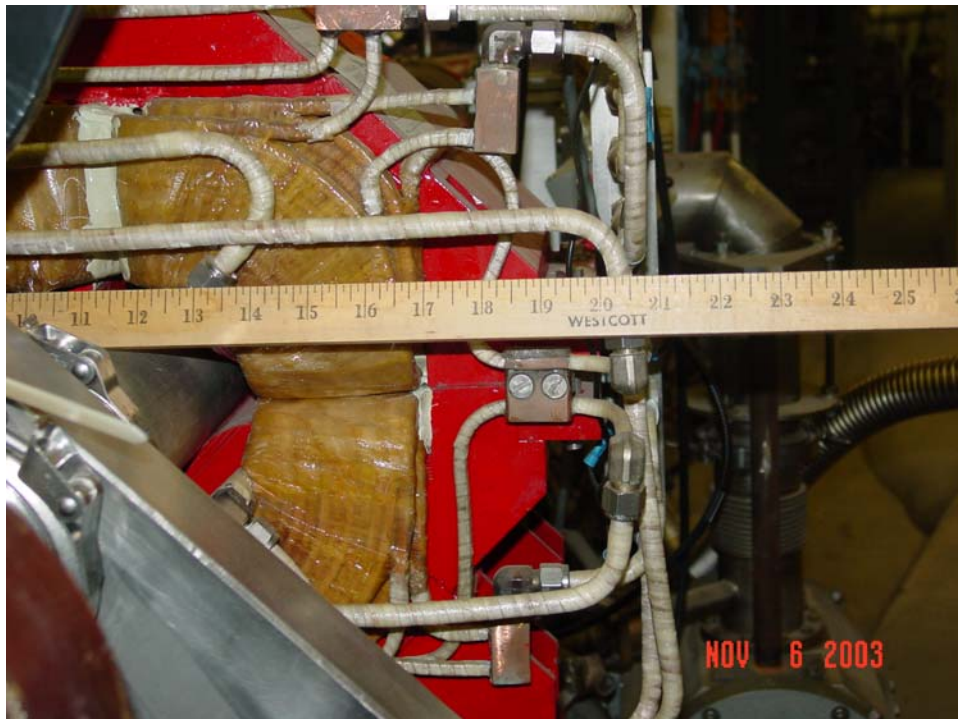


Figure 7. Upstream face of the Q2 magnet where the two horizontal pulsed magnets near the Chopper cause the MTA and Booster beam lines to be separated by 11.8 inches. The proposed MTA beam pipe center will be just below the 23-inch mark on the ruler, passing outside of the apparatus downstream of Q2 as well.

The horizontal pulsed dipoles can be made as shown in Figure 8, below, where the straight-ahead Linac beam (circle) and the MTA beam (ellipse) positions are indicated in the magnet downstream of the Chopper. Note that the vertical pulsed dipole immediately following the Chopper must have sufficient horizontal aperture to accommodate both the straight ahead and MTA beams.

The upstream pulsed-dipole magnet operating at 6.6kG generates the separation of the beam centers of 11 cm at the entrance of the downstream horizontal pulsed dipole magnet. The two horizontal magnets are each 30 cm long and provide 62 mr (3.7 degrees) of deflection at 400 MeV. At Q2 the MTA beam and straight-ahead beam are separated by 30 cm with this arrangement, which allows the MTA beam pipe to pass outside the Q2 coils as shown in Figure 7.

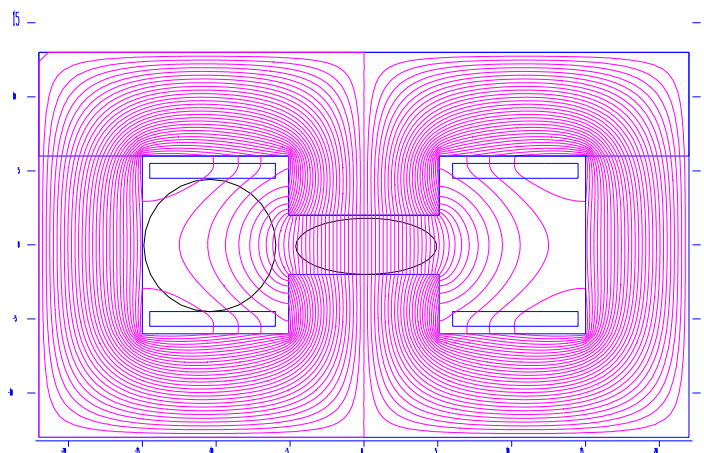


Figure 8. IDH dipole (Main Injector horizontal trim) profile showing field calculation. In the case of the second, downstream pulsed magnet, the straight-ahead Linac beam pipe passes through the magnet between the coils as shown by the circle in the figure.

There was some concern that H^- stripping in the first MTA pulsed dipole at the position of the Bunch Length Monitor might cause the Chopper to break down due to stripped electrons. The simplest solution is to have the Chopper completely off during the pulses that are sent to the MTA. In fact it has to be off since the Chopper plates are not wide enough to cover the beam deflected by the first horizontal MTA dipole. Thus the beam to the MTA cannot easily use the Chopper. Without the Chopper, the two vertical deflection magnets near it should be off for beam to be sent towards the MTA. This argues that the two vertical magnets should be pulsed and not DC. There may be other solutions where there is some vertical magnet in the MTA line that would compensate two DC vertical dipoles on either side of the Chopper, but we haven't looked at them yet.

Figures 9 and 10 show pictures of the up and downstream ends of the Chopper, indicating the changes that are needed to implement this upgrade. The next step in this plan is a careful engineering design of the vacuum pipes to include the four new pulsed magnets and the additional beam line vacuum system starting at the downstream end-plate of the Chopper. Of particular interest is whether a ceramic beam pipe is required for the MTA pulsed dipoles.

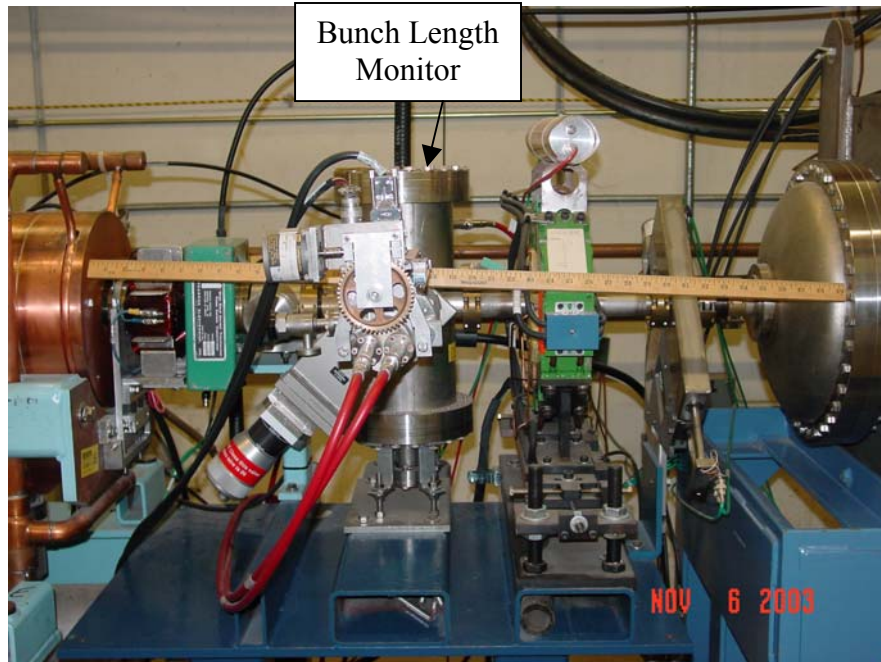


Figure 9. The region between the end of the 400 MeV Linac and the Chopper. A horizontal pulsed dipole magnet will replace the bunch length monitor at the center of the photo. The MTA transfer design assumes the magnet will be 30cm long, although it seems possible that a 40cm long magnet could be put in the available space. A smaller vertical pulsed dipole will be placed near the Chopper.



Figure 10. The downstream end of the Chopper. A small wide-aperture vertical pulsed dipole could be placed just after the Chopper, followed by a horizontal pulsed dipole as shown in figure 8. A new arrangement of the wire scanner, Pearson transformer and Griffin monitor will provide the needed space.